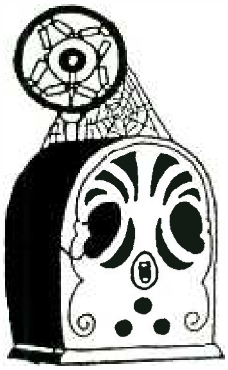
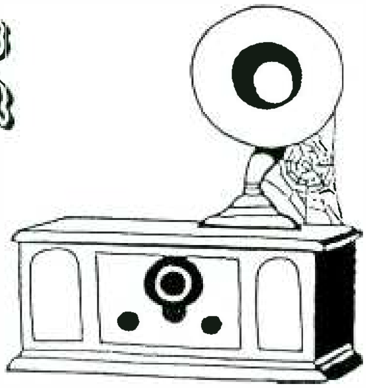


ANTIQUE RADIO CORNER



HOW TO BUILD AND USE A CRYSTAL SET ANTENNA TUNER

By Lance Borden WB5REX

Ever since the earliest days of radio, antenna systems have been used to capture the weak electromagnetic oscillations that transverse the space between transmitters and receivers. In the wireless days, very low frequencies were used because it was believed that the lower frequencies, with their long wavelengths, would propagate farther than short waves because the "near" fields of the long waves extended many miles farther than they did for short waves. Ionospheric bounce, or skip, was unknown to those early pioneers. All radio communication was accomplished by the use of "ground waves."

Theoretically, the ground waves, at lower frequencies, would travel much farther than they would at higher frequencies because the lower frequencies have such a "long wavelength." The physicists told us, and experiment proved, that frequency and wavelength were directly related. It was also proven that there was a direct relationship between frequency and wavelength compared to the speed of electromagnetic propagation; the speed of light.

It is universally accepted that electromagnetic waves **always** travel 300,000,000 meters, or 186,363.6 miles, in one second in free space (one meter is equal to 39.36 inches). This is a **universal constant** and, as far as we know, doesn't vary anywhere in the universe that there is free space for the waves to travel.

From this fact comes the formula for figuring out the wavelength of a signal if only the frequency is known:

$$\text{WAVELENGTH IN METERS} = \frac{300{,}000{,}000}{\text{FREQUENCY IN CYCLES (HERTZ or HZ)}}$$

$$\text{WAVELENGTH IN FEET} = \frac{984{,}000{,}000}{\text{FREQUENCY IN HZ}}$$

...and the formula for figuring out the frequency of a signal if only the wavelength is known:

$$\text{FREQUENCY IN HZ} = \frac{300{,}000{,}000}{\text{WAVELENGTH IN METERS}}$$

$$\text{FREQUENCY IN HZ} = \frac{984{,}000{,}000}{\text{WAVELENGTH IN FEET}}$$

Figure 1A shows an example of the relationship between frequency and wavelength. Because of the large numbers of cycles or Hertz involved in radio, we usually refer to frequency in **KILOHERTZ** (KHZ) for thousands of cycles and **MEGAHERTZ** (MHZ) for millions of cycles.

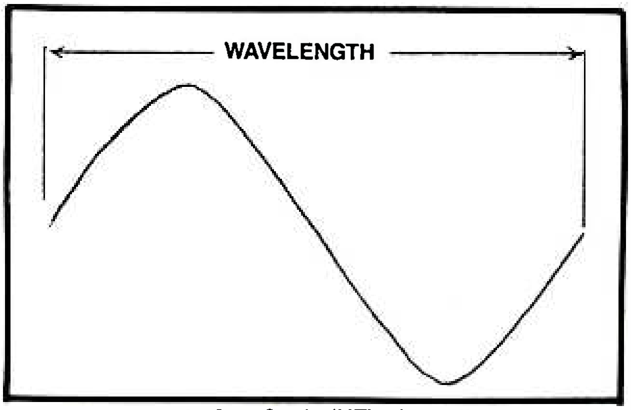


Figure 1A: One Cycle (HZ) of a radio wave

We don't need to go into any complicated math or theory to give you a fair understanding of how all of this works. Antenna theory and design is a very complex science in itself. There are now many different types of antennas for a vast number of applications. For our purposes, with crystal sets and other radios that cover a wide range of frequencies, we normally use what is known as a **"Random Wire"** antenna. This is an antenna that consists of a random length of wire that is not designed for any particular frequency. Because of this, we will only discuss how the random wire antenna works and how it applies to our particular application; crystal sets and other simple radios.

In simple terms, random wire antennas usually work best when their "electrical" length is equal to one-half the wavelength of the signal that is being received. This allows "space" for each half-cycle of the radio wave to transfer the greatest amount of energy possible to the antenna. When an antenna is tuned to the frequency (wavelength) of the desired signal, it is said to be **RESONANT** at that frequency.

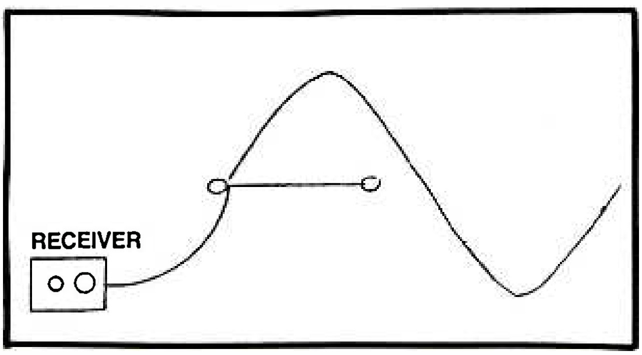


Figure 1B: Antenna is too short and is tuned "above resonance"

If an antenna is too short to be resonant at a certain frequency, it is said to be "tuned above resonance" and would appear to the signal as in Figure 1B. When the antenna is too long to resonate at a given frequency, it is "tuned below resonance" for that frequency and would appear to the signal as in Figure 1C. Figure 1D shows what happens when an antenna is "tuned to resonance" at a particular frequency.

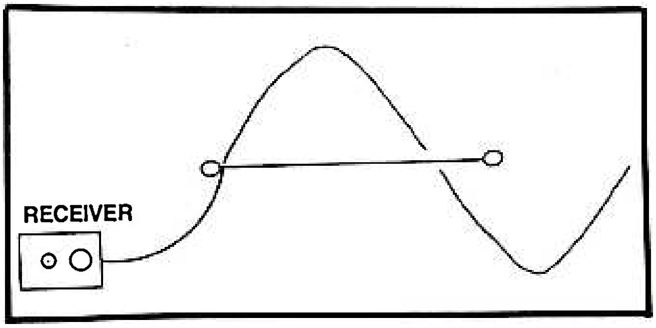


Figure 1C: Antenna is too long and is tuned "below resonance"

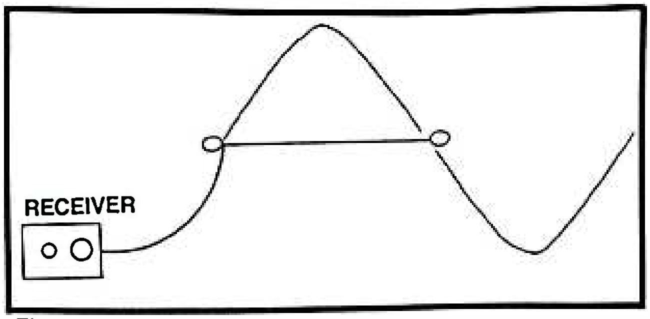


Figure 1D: Antenna length is just right and is tuned "to resonance"

In the early days of wireless, when low frequency, long wave, transmissions were common, wavelengths ran into thousands of meters. Because of these extremely long wavelengths, it would have been very impractical to have antennas thousands of meters long; especially on board ships where space was very limited! Because "necessity is the mother of invention," the early designers found a way around this problem by artificially, or "electrically," tuning their antennas to resonance by using **LOADING COILS.** These "loading coils" were adjustable coils of wire, or **INDUCTORS,** that were connected in series with the antennas to "electrically" add length to them in order to bring about resonance at lower frequencies than would have been possible with the length of the antenna wire alone. A variable capacitor was often connected in parallel with the loading coils to "fine tune" them. Figure 1E shows how loading coils with parallel variable capacitors were used to lower the resonant frequency of antennas.

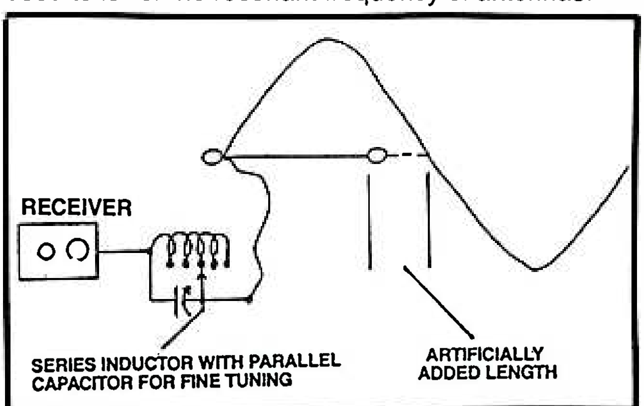


Figure 1E: Antenna is electrically tuned to resonance by using a series inductor to artificially add to its length

During the 1920's, experimenters discovered that shorter wavelength signals could bounce, or **SKIP**, off of the charged gases that formed the **IONOSPHERE.** This skipping action allowed the short wave signals to travel very long distances around the World by "bouncing" from the Earth to the ionosphere and back a number of times. Figure 1G shows how this happens.

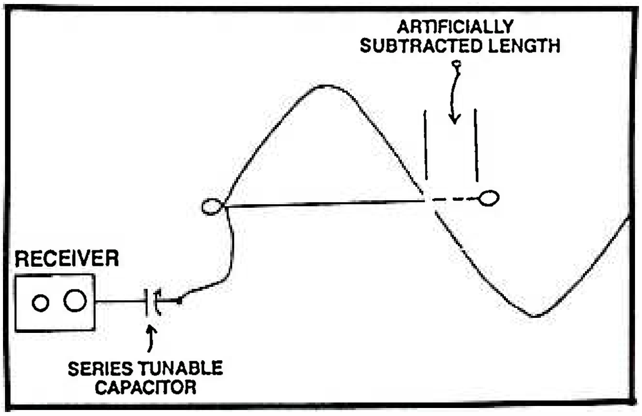


Figure 1F: Antenna is electrically tuned to resonance by using a series capacitor to artificially subtract from its length

The discovery of ionospheric skip brought about the advent of international broadcasting and long distance communications by amateur radio operators (or **HAMs**), commercial, and military stations. Along with the use of short waves came a problem that was opposite to the earlier need for lengthening antennas; many antennas were now **too long** to operate efficiently at these higher frequencies! Necessity again forced the designers to come up with a solution, and of course they did just that by connecting variable capacitors in series with long antennas to artificially shorten them. Figure 1F shows how this was done.

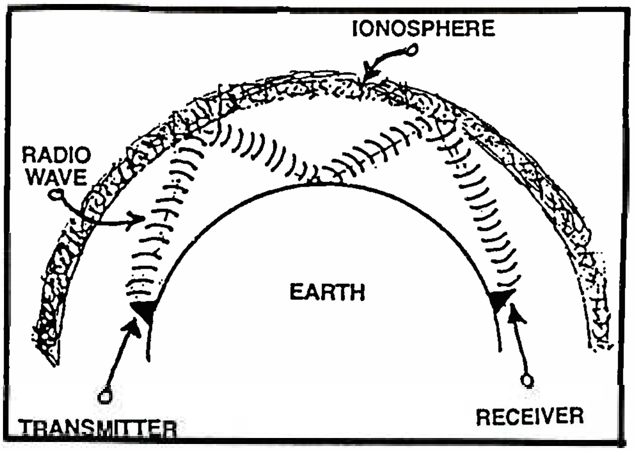


Figure 1G: Radio wave is refracted by the ionosphere and reflected by the earth

Many receivers and transmitters were designed to operate on a wide range of frequencies and it would have been impractical to have a "farm" of antennas tuned to cover them all. The High Performance Crystal Set described in Vol. 14 of **ELECTRONICS HANDBOOK** covers frequencies from the bottom of the A.M. Broadcast band at approximately 500 meters, to the short wave bands at 25, 41, and 60 meters.

Because of this multiple frequency usage, loading coils and series capacitors were combined in order to tune antennas to a large spectrum of frequencies. These combined circuits were called **ANTENNA TUNERS.**

The following is a description of how to build and use an antenna tuner that will work to tune antennas for crystal sets and more complex radios on the short wave and Broadcast bands. By tuning your antenna to resonance, it will transfer the energy from the received radio wave to your set more efficiently. This will result in a louder signal that will allow weaker DX stations to be heard that were not audible before. The antenna tuner can also be used to increase the selectivity of simple receivers. This can help separate the faint DX stations from the strong locals. Assembly of this antenna tuner is accomplished using simple construction techniques and readily available materials.

CONSTRUCTION

Begin construction by acquiring all of the parts and materials you will need before you start. A list of parts, materials, and sources is included at the end of this article. (See Photo #1)

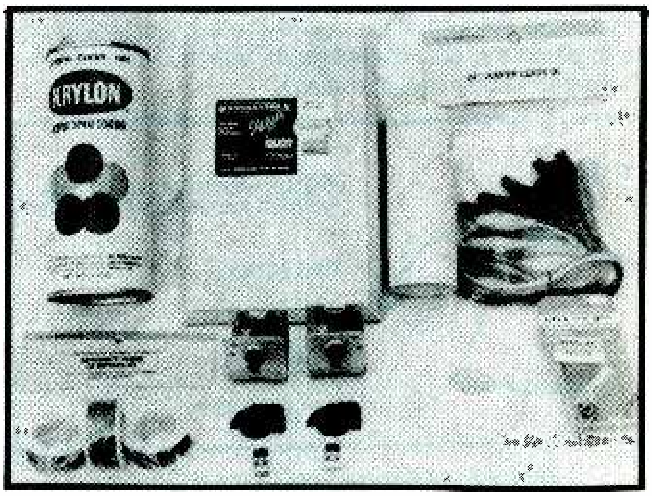


Photo #1: Parts required to build the Antenna Tuner; including acrylic spray, screws, and double-sided foam mounting tape.

Refer to the parts list, photos, and illustrations while building the antenna tuner.

STEP 1. Spray the coil form inside and out with one good coat of clear acrylic spray and let it dry. Spray the board with three coats, letting it dry between coats.

STEP 2. (Refer to Photo #2 and Figure #2) Punch two small holes in the coil form, 1/4 inch apart and 1/2 inch from the end. Pass $4^1/_2$ inches of the 22 AWG coil wire through one hole from the outside of the coil form and then pass it back through the other hole. Repeat this process once more and pinch the resulting loops with pliers to hold the coil lead in place.

STEP 3. (Refer to Photos #2 and 3, and Figures 3 and 4) Wind ten turns, close but not overlapping, on the coil form and make a tap by securing the coil with a piece of tape, then looping the wire around a pencil. Twist the loop twice and then remove the pencil and tape. Wind ten more turns and make another tap using

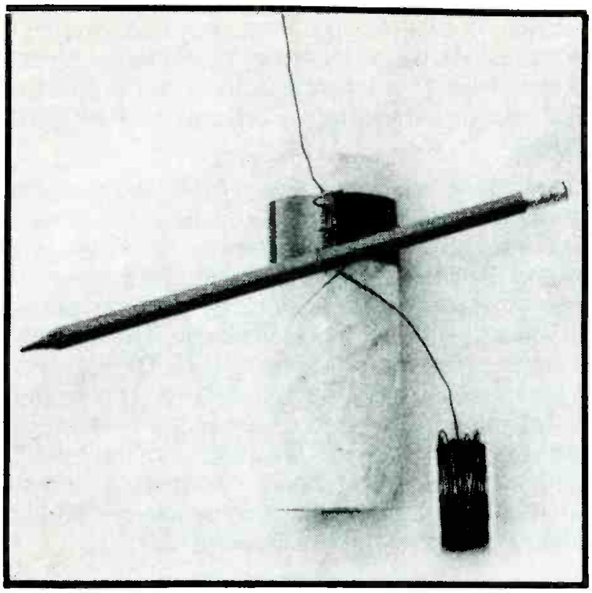


Photo #2: Winding the coil, using tape to hold the coil wire while twisting the taps with a pencil.

the pencil and tape as described above. Repeat this process every ten turns until the ninth tap has been made at the nintieth turn. Punch two holes as in Step 2 and secure the end of the coil at the last tap, using pliers to pinch the wire the same as before. No lead wire is required at this end of the coil.

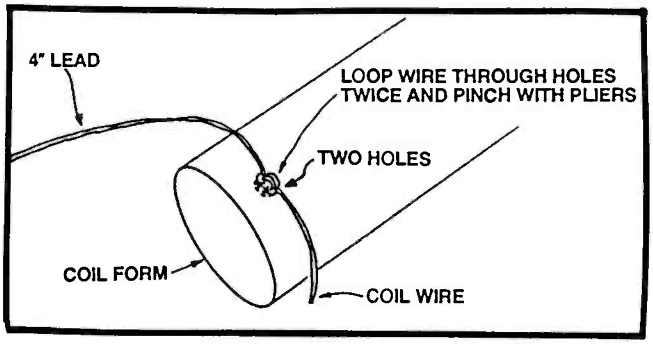


Figure 2: Attaching wire to the coil form

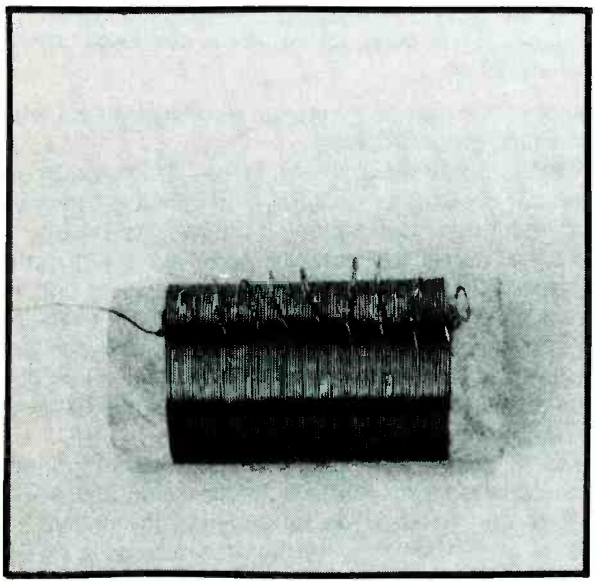


Photo #3: The finished coil.

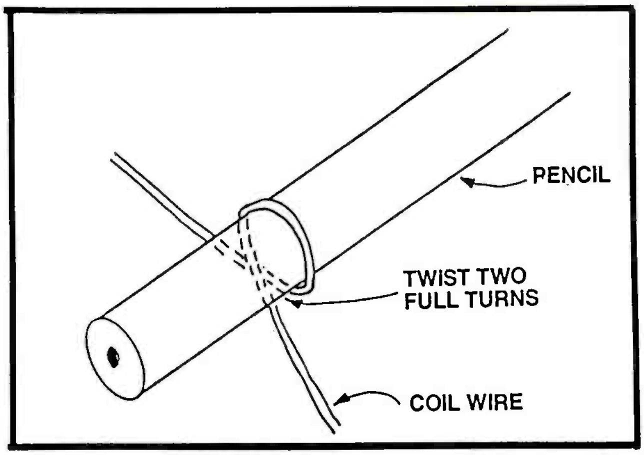


Figure 3: How to twist a coil tap

STEP 4. Spray the coil with three coats of clear acrylic, letting it dry between coats. The clear acrylic will hold the coil winding in place and also will prevent moisture from affecting the coil's efficiency.

STEP 5. The tuning capacitors are 365 picofarad units obtained from one of the suppliers referred to in the parts and source list at the end of this article. Old tuning capacitors obtained from junk AC-DC radios will work fine by connecting the stators of the small sections to the stators of the large sections in order to increase the total capacitance. (The stators are the plates that don't move). Scrape the left rear upper corner (when viewed from the front) of each tuning capacitor frame to remove oxides and deposits, then solder a three inch piece of insulated hook-up wire to it.

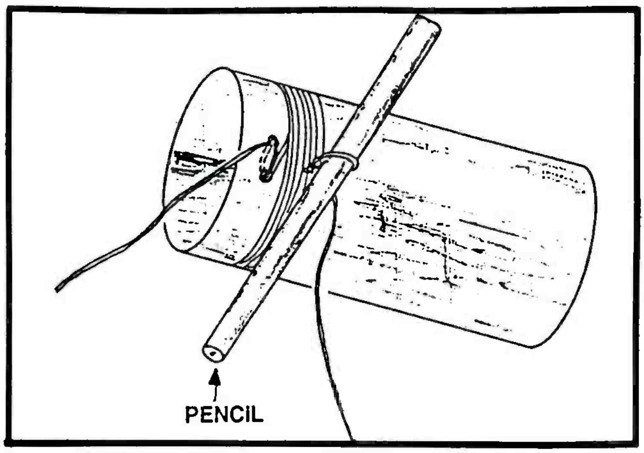


Figure 4: Coil detail

STEP 6. (Refer to Photos #4 and 5 and Figures 5 and 6) Temporarily place the tuning capacitors, coil, and fahnestock clips on the board and lightly outline their locations with a pencil. Use super glue to attach the 3 inch by 1/4 inch coil mounting strips, one inch apart, to the board.

Cut strips of double-sided foam mounting tape to the size of the capacitor bases and press into place on the board. Place the capacitors on the mounting tape and press down hard, being careful not to bend the capacitor plates. Install the fahnestock clips with #4 x 1/2 inch round-head wood screws. Glue the coil to the wood strips with super glue, with the taps pointed up and the

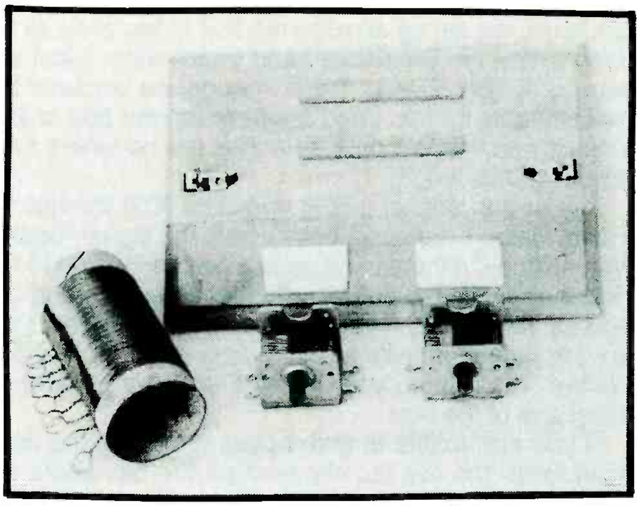


Photo #4: Locating coil, mounting strips, fahnestock clips and double-sided foam mounting tape for capacitors.

lead wire to the left. Install the knobs on the capacitor shafts.

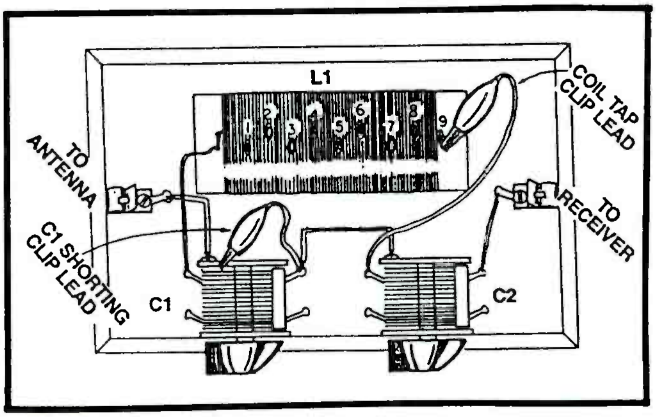


Figure 5: Top view

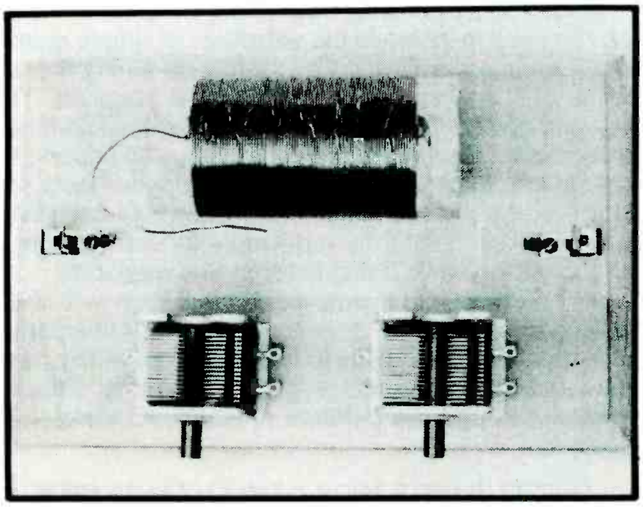


Photo #5: Board with all major parts in place, before wiring.

STEP 7. (Refer to Photo #6 and Figures 5, 6, and 7) Begin wiring the tuner by scraping the enamel off of the end of the coil lead wire and soldering it to the stator lug of capacitor C1, as shown in Figure 5. Trim the case lead wire of capacitor C1 to the proper length and solder it to the antenna fahnestock clip.

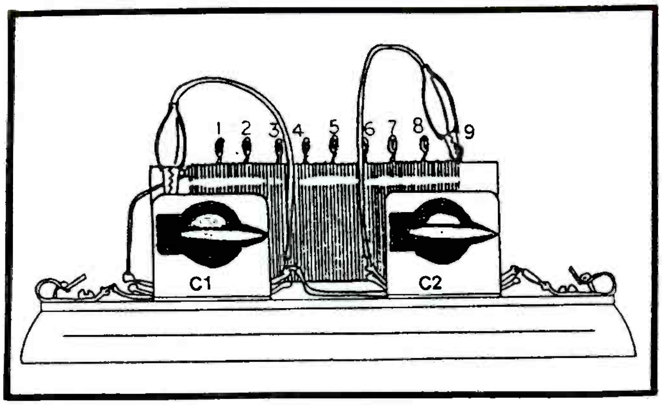


Figure 6: Front view

Cut a piece of insulated hook-up wire to fit between the stator lug of capacitor C2 and the receiver fahnestock clip. Solder this wire in place.

Trim the case lead wire of capacitor C2 to the proper length and connect it to the stator lug of capacitor C1. Do not solder this connection yet.

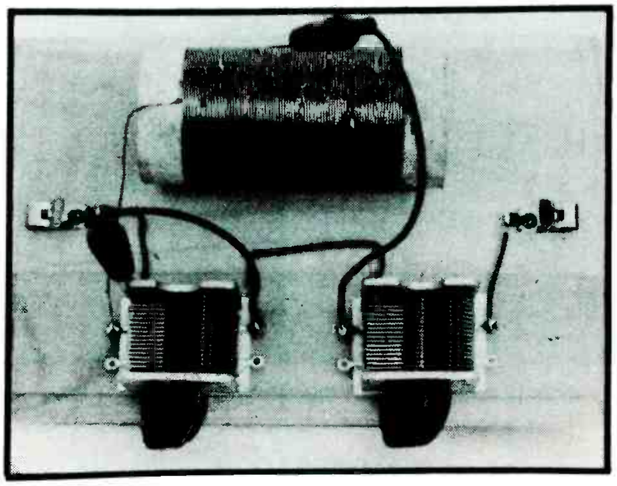


Photo #6: Top view of the completed antenna tuner, showing wiring.

NOTE

Make the clip lead wires as short as possible, while still being able to reach their connections. Making these wires too long will introduce stray capacitance into the circuit that could affect its efficiency; especially at higher frequencies.

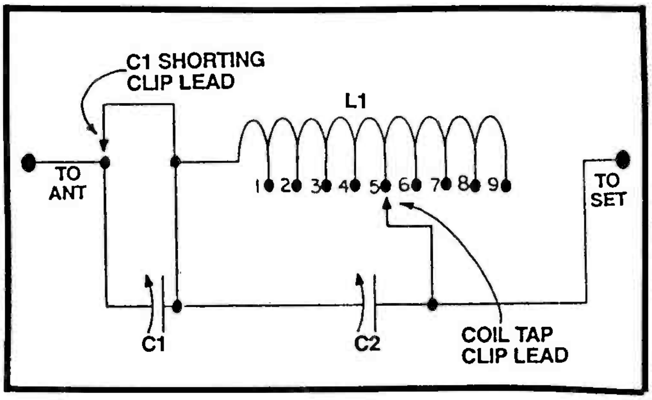


Figure 7: Schematic

Cut the capacitor (C1) shorting clip lead wire to reach from the C1 stator lug to clip onto the C1 upper case. Solder this clip lead wire and the capacitor (C2) case lead wire to the C1 stator lug.

Cut the coil tap clip lead wire to reach from the capacitor C2 stator lug to coil tap #1. Solder this lead wire to the capacitor C2 stator lug.

Use an Exacto knife or razor blade to scrape the enamel off of the coil taps where the coil tap clip lead will connect. This is very important because the weak R.F. (Radio Frequency) signals will not conduct through the enameled coating on the coil wire.

Bend the coil taps alternately to the rear and to the front to facilitate connection with the coil tap clip lead.

This completes the wiring of the antenna tuner.

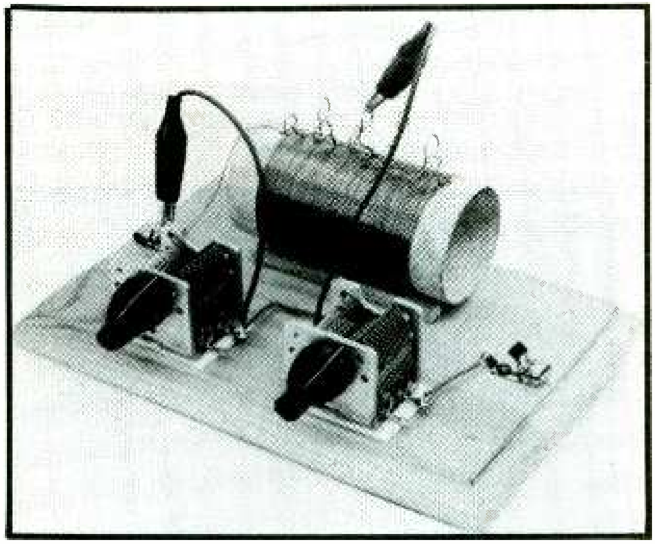


Photo #7: The completed crystal set antenna tuner.

OPERATION

This antenna tuner can be used with crystal sets, one and two-tube sets, antique TRF sets, and any other receivers designed to operate in the A.M. Broadcast band and short wave bands, up to around 30 Mhz. The following is a description of how to connect and operate the antenna tuner on both the Broadcast and short wave bands:

BROADCAST BAND (540 to 1750 Khz)

To use the tuner on the Broadcast band; begin by connecting the antenna fahnestock clip to your antenna and then connect the receiver fahnestock clip to your receiver antenna connector. Connect a good ground, such as a ground rod or metal pipe that has been driven into the ground, to your receiver ground connector.

Bypass the tuner by clipping the C1 shorting clip lead to the case of the series capacitor, C1. Clip the coil tap clip lead to the case of the parallel capacitor, C2. This effectively connects the antenna directly to the receiver without any benefit from the antenna tuner.

Tune the receiver to a weak station in the desired portion of the band. Disconnect the coil tap clip lead from the case of the parallel capacitor C2, and connect it to tap #9 of the coil. This will provide maximum inductance for tuning an antenna that is too short to be resonant at the Broadcast band frequencies. Most antennas are too short at these frequencies because the wavelengths for this band are from around 500 to 200 meters and typical home antennas are no where near even half this length.

Adjust the parallel tuning capacitor (C2) through its range to find if there is a point where the signal "peaks" in amplitude. If there is no peak when connected to tap #9, then move the coil tap clip lead to tap #8 and adjust C2 for a peak. If you still can not find a peak, then try this procedure with all of the taps on the coil, one at a time. You will probably be able to find a peak on at least one of the taps.

If you are unable to find a peak on any of the taps, then leave the coil tap clip lead on the tap where the best signal was obtained and activate the series tuning capacitor (C1) by disconnecting the series capacitor shorting clip lead from C1's case. Tune C1 through its range until you find a point where C2 can be peaked. The series capacitor (C1) can be used to "fine tune" the antenna and is usually most effective at the high end of the Broadcast band. Once parallel capacitor (C2) has been peaked, the antenna has been tuned to resonance.

When changing stations, the Parallel capacitor C2 will require adjusting for maximum amplitude. At the high end of the band the lower numbered taps are usually most effective, and at the low end, the higher numbered taps normally work best.

When used with crystal sets and other simple receivers, it is important to tune the receiver first with the antenna tuner bypassed by connecting the clip leads to the capacitor cases, as previously mentioned. The reason for this is that the antenna tuner will affect the receiver's tuning and can actually be used to change stations with sets like these.

Because of this tuning interaction, the antenna tuner can be used to increase the selectivity of simple receivers. This is accomplished by slightly de-tuning the antenna until an increase in selectivity is apparent. The coil and parallel tuning capacitor C2 can also be tuned as a "notch" filter to help reject a particularly strong local station. Experimentation and practice will help you learn to use this technique. This increased selectivity can really be helpful by reducing interference from a strong station while trying to listen to a weak one.

All antennas differ and experimentation will show which taps and capacitor settings work best in a particular situation. It is helpful to keep a record of tap numbers and capacitor settings that work best for different frequencies and if a different antenna or receiver are used.

SHORT WAVE BANDS (1750 KHZ to 30 MHZ)

The antenna tuner is connected the same way for short wave as it is for the Broadcast band. When initially using the tuner on short wave, the series and parallel tuning capacitors should be shorted with the clip leads to bypass the tuner the same as is done for the A.M. Broadcast band.

Once a station is selected, the taps and capacitors are selected and adjusted the same as they are for the

lower frequency Broadcast band. With most antennas, the parallel tuning capacitor C2 and the lower numbered taps will have the greatest effect on frequencies below about 6 Mhz. As the frequency is increased, the series tuning capacitor C1 will have more influence on the antenna and the coil will begin to have less effect.

Experimentation and practice will show the operator which taps and capacitor settings to use. Again, a record of settings is a useful aid for the operation of this antenna tuner on short wave.

HOW IT WORKS

In order for an antenna to transfer the maximum signal to a receiver at a given frequency, it must be resonant at that frequency. To be resonant at a certain frequency, an antenna must be physically or electrically tuned in length to the wavelength of that frequency. At the lower Broadcast band frequencies, the wavelength exceeds 500 meters and at the higher short wave frequencies, it is less than 10 meters.

For general reception, it is not practical to physically tune an antenna to a particular wavelength by shortening or lengthening the antenna wire. Instead of physically changing the length of an antenna, tuned circuits can be connected between the antenna and receiver that electrically change its length by tuning it to resonance.

If the desired frequency is higher than the antenna's natural resonant frequency, the antenna acts inductively and can be tuned to resonance by using a tunable capacitor in series with it. With our antenna tuner, series capacitor C1 provides this tunable capacitance.

If the desired frequency is lower than the antenna's natural resonant frequency, the antenna acts capacitively and can be tuned to resonance by using a variable inductor connected in series with it. With this tuner, tapped inductor L1 provides this inductance. Parallel tuning capacitor C2 is used to fine tune the inductor to resonance with the antenna.

CONCLUSION

In conclusion, very good results can be expected with this antenna tuner. It has been used successfully with the high performance crystal set described in **ELECTRONICS HANDBOOK,** Volume 12, and with a one-tube set, antique sets, and a commercial multiband communications receiver.

It will tune random wire antennas from approximately fifty feet and longer, to resonance on the A.M. Broadcast and short wave bands up to about 30 Mhz. Shorter antennas, such as whips, can be tuned successfully on the shortwave bands using this tuner.

When connected to a crystal set at this location, signals were louder and more stations could be heard than with just the antenna alone. As a bonus, powerful local stations could be tuned out so weaker, more distant stations could be received clearly.

Good luck with your crystal set antenna tuner and happy DX'ing!! ■

REFERENCES

(1) **RADIOS THAT WORK FOR FREE, K.E. Edwards,** Hope and Allen Publishing, P.O. Box 926, Grants Pass, OR 97526 (Available from **Antique Audio** and **Antique Electronics Supply** for $7.95 plus shipping. Addresses are in the parts/source list.)

(2) **ELECTRONICS SIMPLIFIED-CRYSTAL SET CONSTRUCTION, F.A. Wilson**
Barnard Babani Publishing Ltd.
The Grampians
Shepherds Bush Road
London W6 7NF, England
(Available from **Electronic Technology Today Inc.**
P.O. Box 240
Massapequa Park, NY 11762-0240
Book #BP92, $5.50 plus shipping

(3) **THE RADIO AMATEUR'S HANDBOOK**
American Radio Relay League
225 Main Street
Newington, CT 06111
(Available at electronic supply houses and book stores)

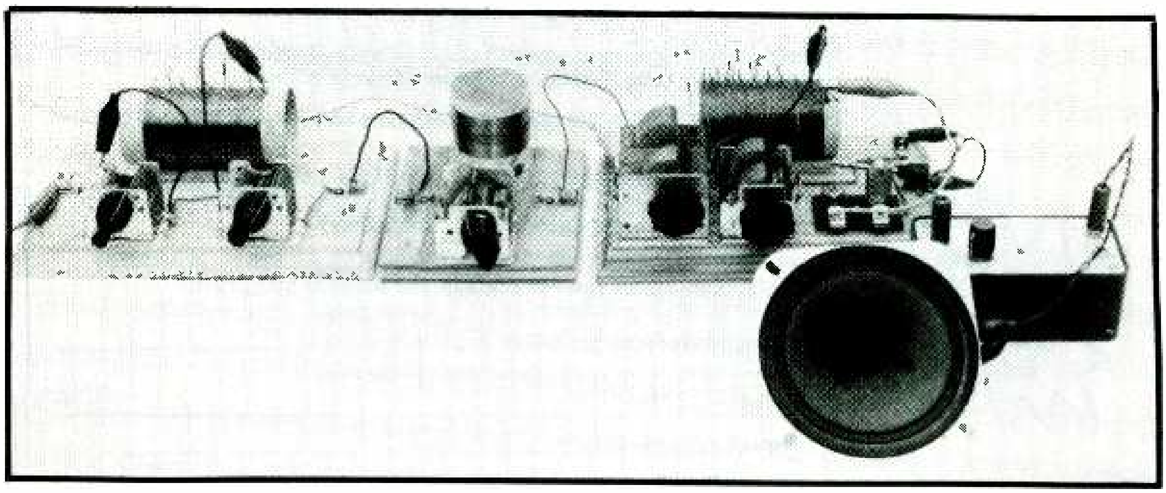


Photo #8: An ELECTRONICS HANDBOOK crystal set listening post, consisting of (left to right:
1. Crystal set antenna tuner from this volume (#15)
2. QRM/Interference rejector from volume #13
3. High-performance crystal set from volume #12
4. Crystal set amplifier & speaker from volume #14

PARTS AND SOURCE LIST FOR CRYSTAL SET ANTENNA TUNER

ITEM	SOURCE
Coil Form	Cardboard toilet paper tube or paper towel tube. Approx. 1½ x 4½ inches. **Note:** Some brands of toilet paper come on tubes that are less than 1½ inches in diameter. Be sure to use a tube that is 1½ to 1¾ inches in diameter.
Coil Wire, 40 feet of #22 AWG enameled copper magnet wire.	Radio Shack or other electronic supply. Radio Shack P/N 278-1345 contains #22, #26, and #30.
Clip Leads	Radio Shack or other electronic supply. Radio Shack P/N 278-1157 contains eight, double-ended clip leads.
Knobs and Hook-up Wire	Radio Shack or other electronics supply.
Fahnestock Clips	Fahnestock clips are available from the three suppliers listed below.
Tuning Capacitors, Approximately 365 Pf variable capacitors	**Antique Audio** 5555 N. Lamar Suite H-105 Austin, TX 78751 (512) 467-0304 P/N CV-365, @ $7.95 Plus shipping. They also carry fahnestock clips, crystal set kits, magnet wire, and parts. Send $2.00 for their catalog.
Tuning Capacitors, Approximately 365 Pf variable capacitors	**Antique Electronic Supply** 6221 Maple Avenue Tempe, AZ 85283 (602) 666-1541 P/N CV-231, @ $6.95 Plus shipping. They too carry fahnestock clips and crystal set parts. Ask for their catalog. **Modern Radio Laboratories** P.O. Box 14902 Minneapolis, MN 55414 MRL sells crystal set kits, parts, and plans. Send $1.00 for their catalog. **NOTE:** Old tuning capacitors salvaged from scrap AC-DC radios will work fine. See text.
Mounting Board, Approximately 4½ x 7 inch plaque or plain board.	Plaques can be purchased at hobby and craft stores. A plain board will work fine as long as it is very dry before spraying with acrylic.
Miscellaneous	**Local Hardware Store.** Clear acrylic spray, #4 x 1/4 inch round head wood screws, double-sided foam mounting tape, and super glue. Coil mounting strips are 3 inch x 1/4 inch balsa wood, but any type wood strips will work.